The Diet of Wintering Double-crested Cormorants Feeding at Lakes in the Southeastern United States

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Abstract.—The diet and potential impact of wintering Double-crested Cormorants (*Phalacrocorax auritus*) on sport fishing were studied during the winters of 1995-96 and 1996-97 at Lake Beulah, Bolivar County, Mississippi, an oxbow lake of the Mississippi River and during the spring of 1997 at Lake Eufaula, a large manmade reservoir on the border of Alabama and Georgia. The diet was determined from analysis of intact fish and otoliths found in the stomachs of 142 cormorants collected at Lake Beulah and 51 cormorants collected at Lake Eufaula. Consistent with previous studies, the diet at both sites consisted primarily of shad (*Dorosoma* spp.) and sunfishes (*Lepomis* spp.), but also included catfish (*Ictalurus* spp.). The catfish in the diet from both areas were most likely taken from nearby catfish ponds. The size of intact fish in the diet averaged 111 mm, but varied with fish species. For the most part, cormorants appeared to consume the fish species most available. However, based on fish availability data from Lake Beulah, cormorants appeared to have a preference for sunfishes, particularly bluegill (*Lepomis macrochirus*). From cormorant bioenergetic projections of bluegill consumed in 1996-97 and the estimated range of bluegill available, cormorants consumed only a small percentage of the bluegill available at Lake Beulah. With the possible exception of their predation on harvestable size bluegill, burgeoning cormorant populations do not appear to have an appreciable negative impact on southern sport fisheries. *Received 25 September 1998, accepted 16 November 1998.*

Key words.—Alabama, diet, Double-crested Cormorants, food preferences, Mississippi Delta, *Phalacrocorax auritus*, predation impact, sport fisheries.

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The diet and potential impact of Double-crested Cormorants on sport and commercial fishing have been studied extensively on their breeding grounds in the Great Lakes and Canada (Craven and Lev 1987; Hobson *et al.* 1989; Johnson and Ross 1996; Ludwig *et al.* 1989; Neuman *et al.* 1997; Ross and Johnson 1995). With few exceptions, these studies suggest that cormorants forage primarily on the most abundant prey, which in these ecosystems is commonly the alewife (*Alosa pseudoharengus*). In contrast, only two studies have examined the diet of wintering cormorants in freshwater habitat of the Southern United States. Campo *et al.* (1993) studied the diet of wintering cormorants at eight public reservoirs in Texas and found that abundant forage species such as shad (*Dorosoma* sp.) were also most prevalent in the diet overall, although at some lakes cormorants took an appreciable portion of sport fish. Glahn *et al.* (1995) studied the diet of cormorants collected from their winter roosts in the Delta region of Mississippi, but could not determine their potential impact on specific sport-fishing lakes.

Dramatic increases of the Double-crested Cormorant throughout its breeding range since the mid 1970s has led to large wintering populations in the mid-South (Jackson and Jackson 1995). Such populations in the Delta region of Mississippi are concentrated in the catfish production area of the east-central Delta and in oxbow lakes along the Mississippi River (Glahn and Stickley 1995). Birds roosting in the east-central Delta forage more extensively on catfish (*Italurus punctatus*) than those roosting along the Mississippi River (Glahn *et al.* 1995). Aerial surveys indicate that many cormorants forage in oxbow lakes along the Mississippi River (Glahn, unpublished data), but little is known about the potential impact of this foraging activity. In recent years roost harassment efforts in the east-central Delta have shifted cormorant roosting activity to the

Mississippi River (Mott *et al.* in press). During the winter of 1994-1995, the Mississippi Department of Wildlife, Fisheries and Parks (MDWFP) received an increased number of complaints from concerned sport fishermen about the large numbers of cormorants foraging on Lake Beulah, a Mississippi River oxbow lake in Bolivar County, Mississippi (Gary Lucas, MDWFP, pers. comm.). During the same winter, the senior author observed as many as 1,500 cormorants on this lake during aerial surveys (Glahn, unpubl. data). Although cormorants did not roost here, this site was within 16 km of the largest roosting congregation of cormorants, estimated to contain > 20,000 cormorants.

We compared the food habits of cormorants observed feeding on Lake Beulah to those of cormorants foraging at Walter F. George Reservoir, commonly known as Lake Eufaula, an important sport-fishing lake in Alabama. Our objectives were to clarify the diet of these wintering birds and determine their potential impact on southern sport fisheries.

METHODS

Lake Beulah is a 389-ha oxbow lake adjacent to the Mississippi River. Typical of many southern lakes, important sport fishes include largemouth bass (*Micropterus salmoides*), bluegill (*Lepomis macrochirus*), channel catfish (*Ictalurus punctatus*), black crappie (*Pomoxis nigromaculatus*) and white crappie (*Pomoxis annularis*). We initiated the study at this lake in February and March 1996, but collected only 21 birds because of low cormorant populations on the lake during that period. We continued the study during the winter of 1996-97 during which we observed and collected birds at one- to two-week intervals between December 1996 and March 1997. During these sampling periods, two observers entered the lake by motor boat at approximately 1000 h and, while traversing its length, counted or estimated the numbers of cormorants on or leaving the water. Following each survey, the observers collected varying numbers of cormorants with 12-gauge "3 inch" magnum shotguns and BB-size steel shot. Immediately following collection, the stomach and esophagus of each bird were removed and stored on ice in a labeled plastic bag for later analysis. As part of another study (Glahn *et al.* in press), we also collected cormorants from Lake Eufaula, a large manmade impoundment of the Chattahoochee River on the border of Alabama and Georgia. These specimens were collected in March and April 1997 and processed in an identical manner.

For specimens collected at Lake Beulah, we identified and measured all intact and partially intact fish from the stomach contents following procedures of Glahn *et al.* (1995). Length measurements were used in species-specific length-to-weight equations to obtain the percent biomass of each species in the diet (Kohler and Hubert 1993; Murphy and Willis 1996). We also identified and counted fish otoliths found in samples collected in 1996-97. Because few intact fish were found in the stomach contents of cormorants collected from Lake Eufaula, otolith analysis was the primary means used to examine their diet. To collect otoliths from digested fish in these samples, we washed the entire stomach contents through both #30 and #60 brass sieves. Otoliths found from thorough searches of the #60 sieve were air dried, stored in labeled vials and examined under a 0.7-3.0 × dissecting microscope. Otoliths were identified to genera and sometimes to species, using a reference collection and consulting with fishery experts. The number of fish per species was estimated from pairs of sagittal otoliths found. Because of possible otolith erosion during digestion (Johnstone *et al.* 1990), we did not attempt to determine the length of fish from otoliths. Instead, we aged *Lepomis* spp. by counting the hyaline and adjacent opaque bands of sagittal otoliths (Murphy and Willis 1996). From these age classifications, we assessed the median fish length from previous length-frequency data from Lake Beulah (Lucas and Powell 1992).

Based on the similarity in diet between years at Lake Beulah, we averaged the numbers of identifiable species between years to obtain a composite diet. We compared this composite diet to the most recent data (1995) on fish availability based on gill net, trammel net and hoop net sampling at Lake Beulah (Jan Hoover, U.S. Corps of Engineers, per. comm.). Similarly, we compared the diet of cormorants at Lake Eufaula to 1997 data on fish availability based on gill net sampling (Paul Loska, Georgia Department of Natural Resources, per. comm.). In both cases, the percent of fish species in the diet was compared to the percent availability in the respective lake using Chesson's Alpha (α) as a measure of prey selection (Chesson 1978). This measure rates preference from 0 to 1, where values approaching 0 are least preferred and values approaching 1 are most preferred.

Based on the average number of cormorants observed foraging on Lake Beulah, the fish species composition by weight of the cormorant diet, and the average daily cormorant food demand (Glahn and Brugger 1995), we estimated the number of shad and bluegill removed from the lake over the four-month period of observations. We used the following equation to calculate the number of each fish species consumed per month by cormorants (DCCO) and totaled the number of fish for all months:

Mean DCCO counted × Days/month × 500 g/DCCO/day × % of fish species in diet ÷ Mean grams/fish

RESULTS

Of 21 cormorants collected at Lake Beulah in February and March 1996, 14 had 69 identifiable fish remains. Because only a small number of fish could be measured, we summarized the data only according to percent occurrence in stomachs and percent by number of fish identified.

The two shad species, gizzard (*Dorosoma cepedianum*) and threadfin (*Dorosoma petenen-*

Table 1. Numbers of Double-crested Cormorants estimated foraging on the lake and numbers of cormorants collected at Lake Beulah, Bolivar County, Mississippi, during the winter of 1996-1997.

Date	Numbers estimated	Numbers collected
4 December 1996	150	0
10 December 1996	100	3
17 December 1996	500	2
9 January 1997	5000	7
14 January 1997	40	0
23 January 1997	3000	18
30 January 1997	5000	24
3 February 1997	5000	33
12 February 1997	4000	29
4 March 1997	400	11

sis) that were combined in these samples, occurred in 85.7% of the stomachs and comprised 92.7% of the fish identified. One black crappie occurred in each of two stomachs and the only crappie measured was 210 mm long. One unidentified sunfish, most likely a bluegill, also occurred in each of two stomachs, and one white bass (*Morone chrysops*) occurred in one stomach.

Cormorants collected at Lake Beulah in the winter of 1996-97 varied with numbers observed on the lake and other factors (Table 1). Of 123 cormorant stomachs examined from these collections, we found identifiable fish remains in 102 specimens. Gizzard shad was the most abundant and frequently occurring food item and comprised the largest percent by weight (Table 2). Bluegill and threadfin shad were the only other species that occurred in more than one percent of the stomachs. Sizes of 481 fish averaged 111 ± SE of 1.76 mm, but varied ($F_{5,480}$ = 20.57, P = 0.0001, one-factor ANOVA) with species (Table 2). Approximately 81% of the fish consumed ranged in length from 76 mm to 150 mm (Fig. 1).

From examination of otoliths, we estimated that 1,115 fish had been consumed by the 123 cormorants at Lake Beulah and 352 fish had been consumed by the 51 cormorants at Lake Eufaula. With the exception of the genus *Ictalurus* identified in samples from Lake Beulah, the proportions of genera identified were consistent with data from intact fish (Table 3), suggesting that *Dorosoma* species was the most important genus in the diet. Where identified, the *Lepomis* species was bluegill, the *Ictalurus* species was channel catfish, the *Aplodinotus* species was fresh-water drum (*Aplodinotus grunniens*) and the *Cyprinus* species was common carp (*Cyprinus carpio*). Aging of 31 uneroded *Lepomis* otolith pairs revealed that 16 (51.6%) were age 0 (young of the previous summer), 11 (35.4%) were age one and three (10%) were age two or older. Based on length-fre-

Table 2. The percent frequency of occurrence in stomachs (% Frequency), percent of fish identified (% Fish), their total length and percent biomass (% Weight) of prey species found in the diet of Double-crested Cormorants foraging at Lake Beulah, Bolivar County, Mississippi, during the winter of 1996-1997.

			Total fish length (mm)			
Species	% Frequency	% Fish	N	Mean[1]	SE	% Weight
Gizzard shad	67.6	79.2	381	114.4^{A}	1.9	74.5
Threadfin shad	5.9	7.3	35	63.2^{B}	2.9	0.8
Unid. shad	18.6	11.6	56	111.6^{A}	5.1	11.4
Bluegill	5.9	1.3	6	182.3^{C}	8.9	11.2
Freshwater drum	1.0	0.4	2	183.5^{AC}	7.5	1.8
Brook silverside	1.0	0.2	1	63.0	—	0.3

[1]Means not sharing the same letter differed (P < 0.05 Tukey's).

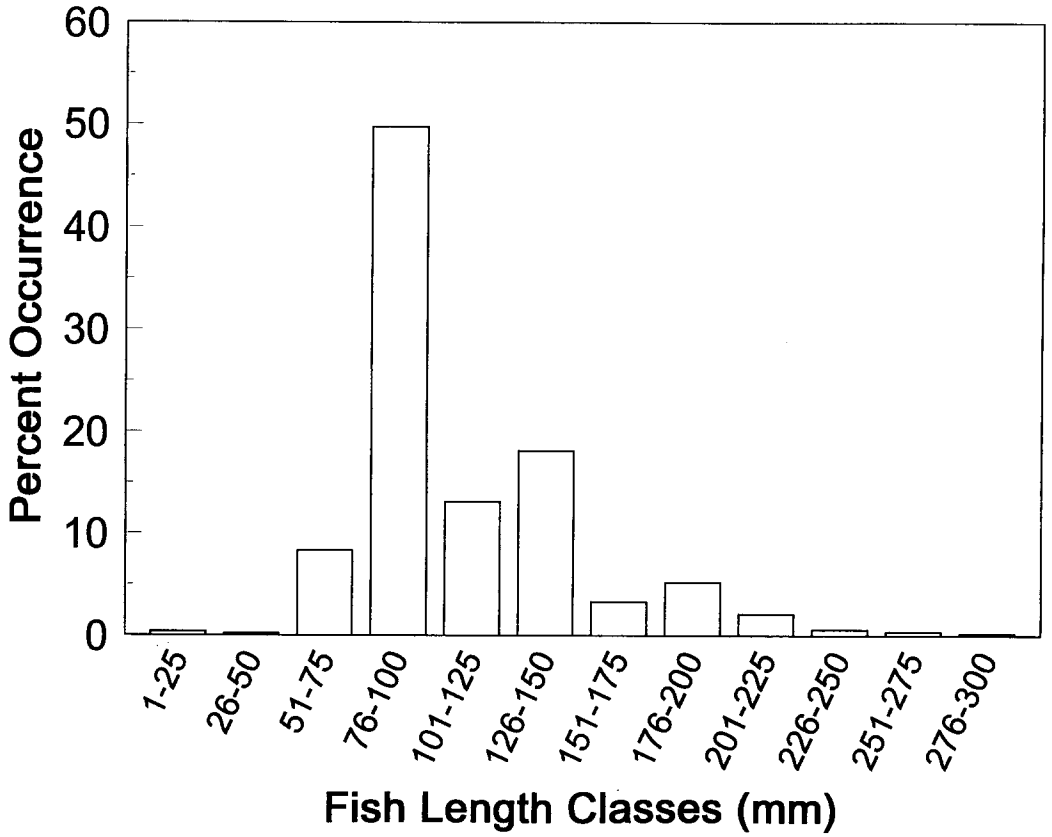

Figure 1. The percent frequency of total length size classes for fish consumed by Double-crested Cormorants at Lake Beulah, Bolivar County, Mississippi, December 1996-March 1997.

quency analysis, the median length of these age classes would be approximately 60 mm, 130 mm and 190 mm, respectively.

Data from Lake Eufaula were similar to that of Lake Beulah with respect to the genera consumed (Table 3). However, there were fewer shad in the diet and more centrarchids and ictalurids (Table 3). These centrarchids were most likely *Lepomis* spp., but could not be positively identified because of otolith erosion. Where identified, the ictalurids were channel catfish. Of 21 uneroded *Lepomis* otoliths aged, 47.6% were age 0, 38.1% were age one and 14.3% were age two or older.

A composite diet from both years of collections at Lake Beulah was calculated at 88.9% gizzard shad, 8.1% threadfin shad, 1.6% bluegill, 0.5% black crappie, 0.5% fresh-water drum, 0.2% white bass, and 0.2% brook silverside (*Labidesthes sicculus*). Considering the relative abundance of these species in Lake Beulah, the only prey species preferred (consumed proportionally more than its abundance) was the bluegill (α = 0.783). The least preferred species were the black crappie (α = 0.0022) and the fresh-water drum (α = 0.0025). Although both gizzard shad and threadfin shad were available in approximately equal numbers, cormorants preferred (α = 0.917) gizzard shad over threadfin shad.

At Lake Eufaula there appeared to be no preference for shad, centrarchids or ictalurids by cormorants, based on fish availability; Chesson's Alpha (α) was 0.26, 0.38 and 0.35, respectively. In contrast to Lake Beulah, Lake Eufaula had a ratio of 2.4 to 1 threadfin shad to gizzard shad. Of 52 intact shad identified in the stomach contents from Lake Eufaula, the ratio of threadfin shad to gizzard shad was 2.2 to 1.

Table 3. The percent frequency of occurrence in stomachs (% Frequency) and percent of fish identified (% Fish) of prey genera as determined by otolith examination in the stomach contents of Double-crested Cormorants collected at Lake Beulah, Bolivar County, Mississippi and Lake Eufaula, Barbour County, Alabama, during the winter (December through March) and spring (March and April) of 1997, respectively.

	Lake Beulah		Lake Eufaula	
Fish Genera/Family	% Frequency	% Fish	% Frequency	% Fish
Dorosoma	89.4	93.4	70.6	77.8
Lepomis	17.8	3.3	17.6	3.7
Unid. Centrarchidae	—	—	31.7	6.8
Ictalurus	8.9	1.8	29.4	11.4
Aplodinotus	3.2	0.6	—	—
Cyprinus	0.8	0.1	—	—
Micropterus	—	—	1.9	0.3
Unidentified	5.6	0.3	—	—

Based on bluegill comprising 11.2% of the cormorant diet by weight at Lake Beulah and bluegills consumed averaging 132.7 g, cormorant populations at Lake Beulah were estimated to consume 107,000 bluegills over the period from December to March. Considering gizzard shad and threadfin shad together comprising 86.7% of the cormorant diet by weight, cormorants were estimated to consume approximately 9.2 million fish of these two species combined.

DISCUSSION

Consistent with cormorant diet at Texas reservoirs (Campo *et al.* 1993), cormorants foraging in an oxbow lake in the Delta region of Mississippi subsisted almost exclusively on shad and sunfish. Based on our analysis of otoliths, the same was true of cormorants foraging at Lake Eufaula in Alabama, except that there was a substantial number of ictalurids in the diet. In contrast to cormorants in Texas, where the percent fish in the diet was 69% threadfin shad and 10% gizzard shad, wintering cormorants at Lake Beulah consumed primarily gizzard shad. The generally smaller size of threadfin shad relative to gizzard shad (Mette *et al.* 1996) accounted for the differences in the prey size distribution between studies. Whereas most of the fish consumed in Texas reservoirs were less than 75 mm in length, most of the fish consumed in our study were greater than 75 mm in length. Glahn *et al.* (1995) reported that the mean size of fish other than catfish consumed, primarily gizzard shad, to be 117 mm. This is consistent with the mean size of fish reported here for Lake Beulah. Previous electrofishing data (MDFWP Files) suggest that most threadfin shad in Lake Beulah range from 60 to 90 mm, while most gizzard shad in the same lake range from 100 to 200 mm. Given the reported equal numbers of threadfin shad and gizzard shad in Lake Beulah (Jan Hoover, U.S. Corps of Engineers, pers. comm.), cormorants appeared to prefer gizzard shad over threadfin shad. We speculate that this is because gizzard shad represent a more optimally-sized prey for cormorants. However, at Lake Eufaula where threadfin shad greatly outnumbered gizzard shad, threadfin shad were taken proportional to their relative abundance. This was also probably the case with cormorant prey selection at Texas reservoirs (Campo *et al.* 1993). Availability, rather than fish size, is probably the most important factor in prey selection by cormorants, but given equal availability cormorants prefer prey fish that are greater than 75 mm. Another factor might be the accessibility of the prey fish. We speculate that crappie and fresh-water drum did not occur in the diet in proportion to their availability because they occur in deep water during the winter and are thus less accessible to cormorants than shad or sunfish.

The occurrence of species other than shad in the diet varied with years, location and methods of analysis. At Lake Beulah, crappie were completely absent in the diet

during 1997, as well as in the diet of cormorants collected at Lake Eufaula. Because cormorants were collected at Lake Beulah later in March of 1996, we speculate that crappie taken during this year were spawning fish. Angler surveys (Allen 1996) indicate that prior to spawning, crappie remain in deep water and may be less accessible to predation by cormorants. Based on otolith analysis, catfish may also be important prey, particularly at Lake Eufaula. Because catfish occurred in the otolith analysis and not the intact fish analysis at Lake Beulah, we speculate that most of these fish were obtained by cormorants foraging at nearby catfish ponds the previous day. Similarly, at Lake Eufaula, cormorants have been reported to feed intensively at a nearby catfish pond that had been constructed for recreational fishing (Paul Loska, Georgia Department of Natural Resources, pers. comm.).

If cormorants are having any impact on sport fishing, it might be from the consumption of bluegill and other sunfishes. Based on their complete absence in gill nets, trammel nets and hoop net samples, bluegill and other sunfishes were the most highly preferred prey species consumed by cormorants at Lake Beulah. However, these techniques may be biased against capturing bluegill relative to other species (Powell *et al.* 1971) and thus the preference may be overstated. Nevertheless, bluegill and other sunfishes appeared to be important in the diet of cormorants at both Lake Beulah and Lake Eufaula, a finding consistent with results at Texas reservoirs (Campo *et al.* 1993). Considering the average size (182 mm) of intact bluegill consumed at Lake Beulah, cormorants in this instance would be in direct competition with anglers for this important pan fish. However, the estimated size distribution of bluegill from otolith aging suggests that less than half of the bluegill captured by cormorants were of harvestable size. We estimated from our analysis of intact fish that cormorants consumed slightly in excess of 100,000 bluegill during the winter months. The total number of bluegill consumed may be greater if the average size of bluegill, as estimated from otolith analysis, were smaller.

What is also unclear is the extent to which cormorants obtained their total daily fish needs from Lake Beulah. Despite these possible errors, the number of bluegill consumed appeared to be only a small percentage of total populations expected to occur in the lake. However, if cormorants are selecting for harvestable size bluegill, their potential impact could be much greater. A range of measured fish densities (fish/ha) from several years of adjusted cove rotenone data for nearby lakes in the region (Gary Lucas, Mississippi Department of Wildlife Fisheries and Parks, pers. comm.) indicated that bluegill occur at densities from 2,174 to 11,554 fish/ha. Based on a surface area of 389 ha, Lake Beulah would support a bluegill population ranging from 846,000 to 4.5 million fish, of which two to 54% would be of harvestable size. Determining the impact of cormorant predation on bluegills is difficult because of the wide variation in bluegill population structure between years. To adequately address this question, additional studies should involve intensive sampling of bluegill populations concurrent with dietary studies of cormorant utilization of this prey base.

Shad is clearly the most important prey species of cormorants foraging at southern lakes, but the impact on this important forage base for predaceous fish appears to be negligible. Despite cormorants possibly consuming 9.2 million shad from Lake Beulah, adjusted cove rotenone data from nearby lakes (Gary Lucas, Mississippi Department of Wildlife Fisheries and Parks, pers. comm.) suggest that combined gizzard shad and threadfin shad populations at Lake Beulah range from 68 million to 318 million fish. Such extreme population fluctuations might result in substantial differences in the diet of cormorants between years and locations; however, even with very low shad populations at Lake Eufaula in 1997 (Paul Loska, Georgia Department of Natural Resources, pers. comm.), they still comprised most of the cormorant diet.

The identification of otoliths from the stomach contents of cormorants was a useful technique for examining the diet from stomach contents that were almost completely digested. This analysis revealed a diet quite

similar to that estimated from intact fish. However, finding large number of otoliths in the stomachs of cormorants collected at midday appeared inconsistent with the notion that most otoliths would be regularly expelled in pellets each morning (Derby and Lovvorn 1997).

With the possible exception of their predation on harvestable size bluegill, cormorants do not appear to have an appreciable negative impact on the sport fisheries at the two lakes studied. This was despite exceptionally large cormorant populations foraging at Lake Beulah. Cormorants primarily prey on forage species and age classes of sport fish that are the most abundant and readily accessible in these ecosystems, namely shad and sunfishes.

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